

WASI-2D: A free software for inverse modelling of multi- and hyperspectral water images

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Introduction

Motivation: Lack of freely available software for

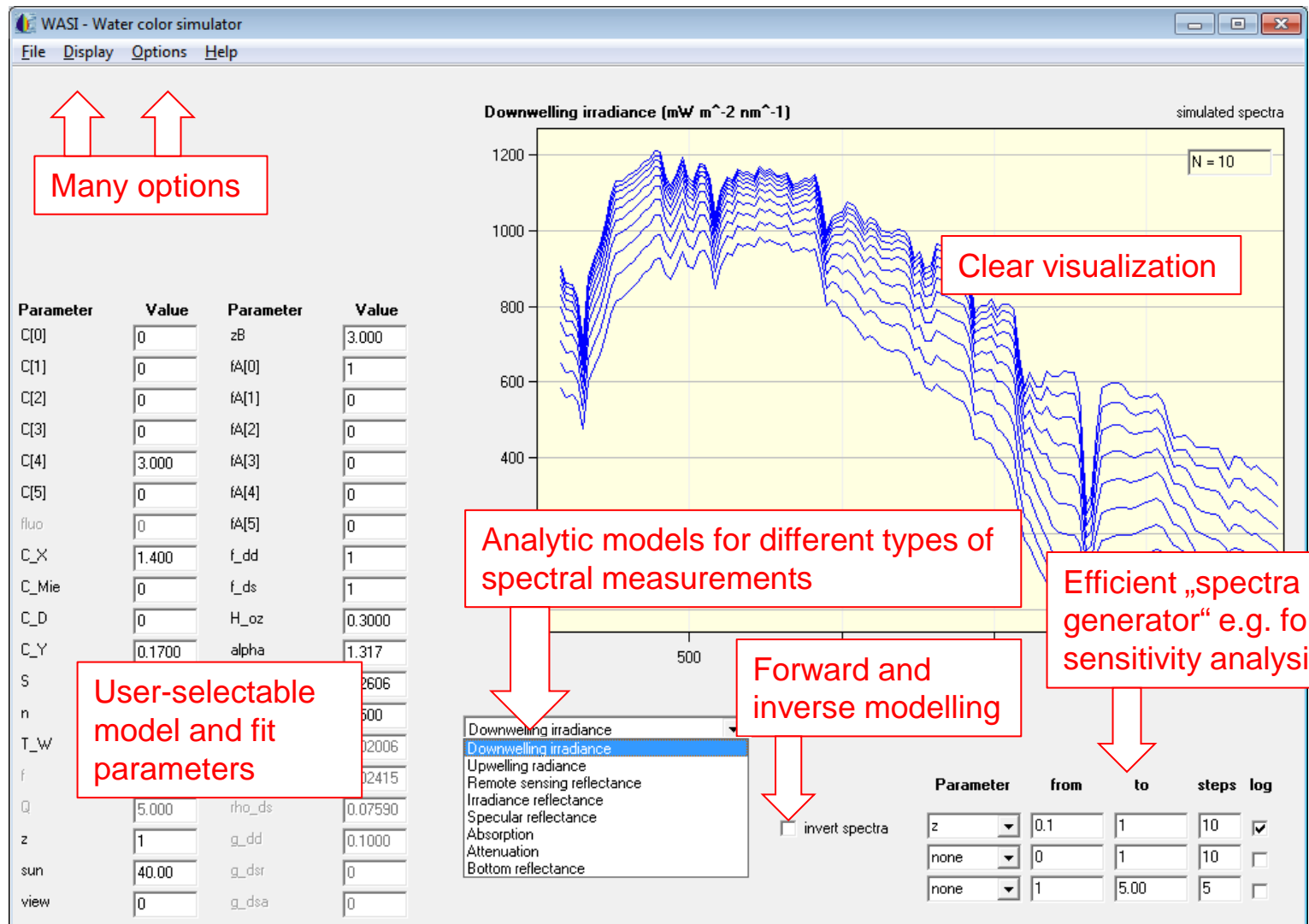
- All types of water (oceanic, coastal, inland, shallow)
 - Site specific adaptation of model parameters incl. optical properties
 - Physical approach (analytic models)
- All calibrated sensors (airborne and satellite; multi- and hyperspectral)
 - Sensor specific adaptation

Goal: Wide range of applications

- Software easy to use
 - GUI, stand-alone, user manual
- Models consistent to in-situ models (Cal/Val)
 - WASI-2D implemented as module into Water Color Simulator WASI

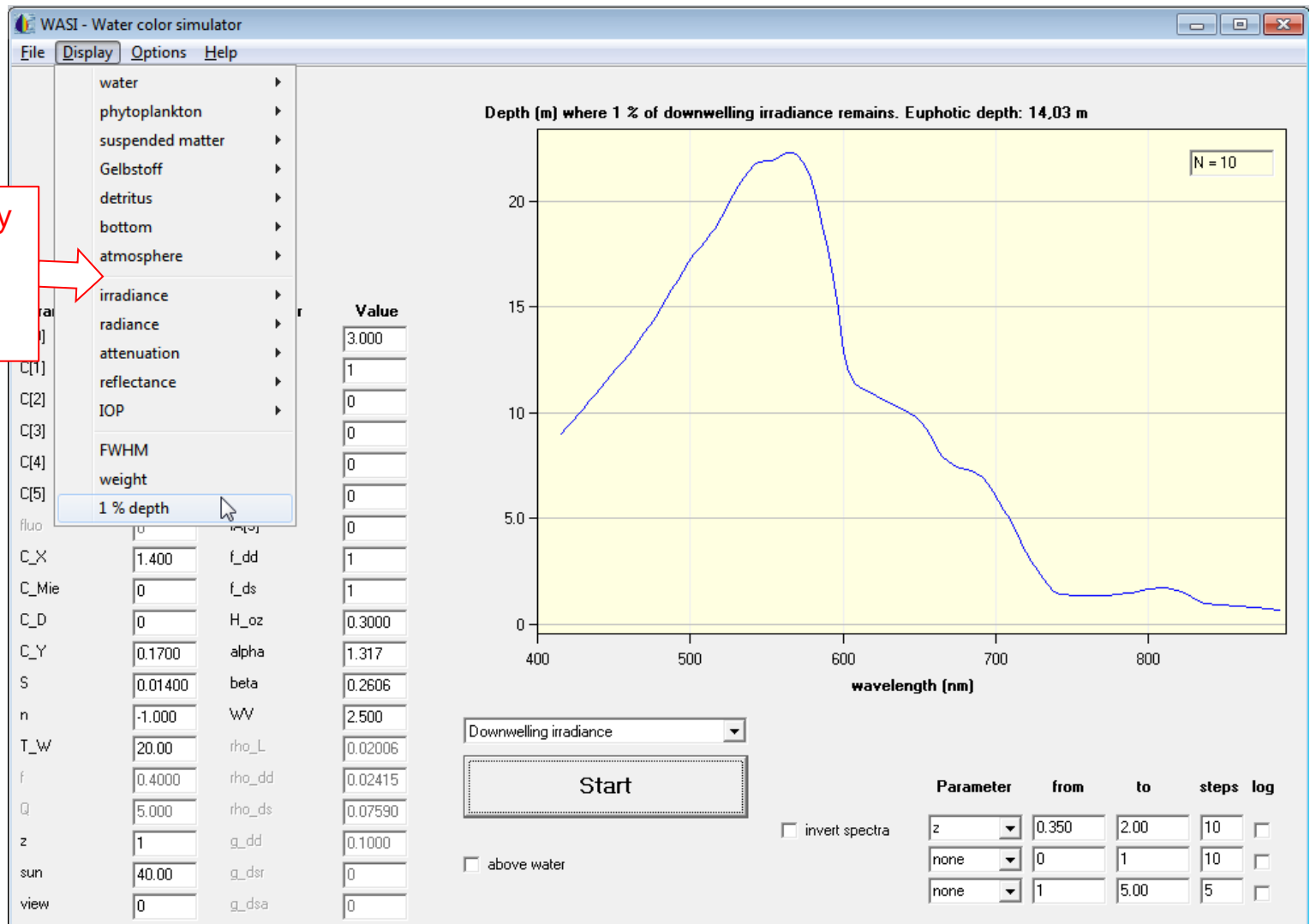


The Water Color Simulator WASI: GUI



WASI: Options

Display internally
used spectra
and spectra of
interest



WASI: Options

Program options

Options of 2D module

WASI - Water color simulator

File Display **Options** Help

Models
 Forward calculation
 Invers calculation
 Reconstruction mode
 Data format
 Directories
 Display
 General
2D

| | | |
|-------|---------|--------|
| 0 | zB | 3.000 |
| C[1] | 0 | fA[0] |
| C[2] | 0 | fA[1] |
| C[3] | 0 | fA[2] |
| C[4] | 3.000 | fA[3] |
| C[5] | 0 | fA[4] |
| fluo | 0 | fA[5] |
| C_X | 1.400 | f_dd |
| C_Mie | 0 | f_ds |
| C_D | 0 | H_oz |
| C_Y | 0.1700 | alpha |
| S | 0.01400 | beta |
| n | -1.000 | WV |
| T_W | 20.00 | rho_L |
| f | 0.4000 | rho_dd |
| Q | 5.000 | rho_ds |
| z | 1 | g_dd |
| sun | 40.00 | g_dsr |
| view | 0 | g_dsa |

2D options

Hyperspectral image
 Use settings from ENVI header ☒
 Width 500 pixels
 Height 500 pixels
 Bands 160
 Header 0 bytes
 Data type 12: 16-bit unsigned integer
 Interleave BSQ
 x scale 1000
 y scale 31416

Preview image
 3 bands ☒
 Scale bands together ☒
 Blue band 12
 Green band 41
 Red band 55
 Contrast 0.250
 Use look-up table ☒
 rainbow3.lut

Mask
 Mask band 103
 Mask values below 0
 Mask values above 0.0040
 Color set

Preview during inverse modeling
 Parameter zB
 Range: from 5.00 to 0
 Update spectrum after 10 pixels

OK Cancel

Downwelling irradiance

Start

☐ above water

☐ invert spectra

| Parameter | from | to | steps | log |
|-----------|-------|------|-------|--------------------------|
| z | 0.350 | 2.00 | 10 | <input type="checkbox"/> |
| none | 0 | 1 | 10 | <input type="checkbox"/> |
| none | 1 | 5.00 | 5 | <input type="checkbox"/> |

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Models

- Reflectance: Albert^{1,2}
 - Deep and shallow waters
 - Empirical coefficients adjusted using Hydrolight
 - Similar to model of Lee^{3,4}
 - Downwelling irradiance: Gregg and Carder⁵
 - For conversion reflectance \leftrightarrow radiance
 - For calculation of sunglint and skyglint
1. Albert, A., Mobley, C.D. (2003). An analytical model for subsurface irradiance and remote sensing reflectance in deep and shallow case-2 waters. *Optics Express*, 11, 2873-2890.
 2. Albert, A. (2004). Inversion technique for optical remote sensing in shallow water. Ph.D. Dissertation, Universität Hamburg, Germany, 188pp.
 3. Lee, Z.P., Carder, K.L., Mobley, C.D., Steward, R.G., Patch, J.S. (1998). Hyperspectral remote sensing for shallow waters: 1. A semianalytical model. *Applied Optics*, 37, 6329-6338.
 4. Lee, Z.P., Carder, K.L., Mobley, C.D., Steward, R.G., Patch, J.S. (1999). Hyperspectral remote sensing for shallow waters: 2. Deriving bottom depths and water properties by optimization. *Applied Optics*, 38, 3831-3843.
 5. Gregg, W.W., Carder, K.L. (1990). A simple spectral solar irradiance model for cloudless maritime atmospheres. *Limnology and Oceanography*, 35, 1657-1675.



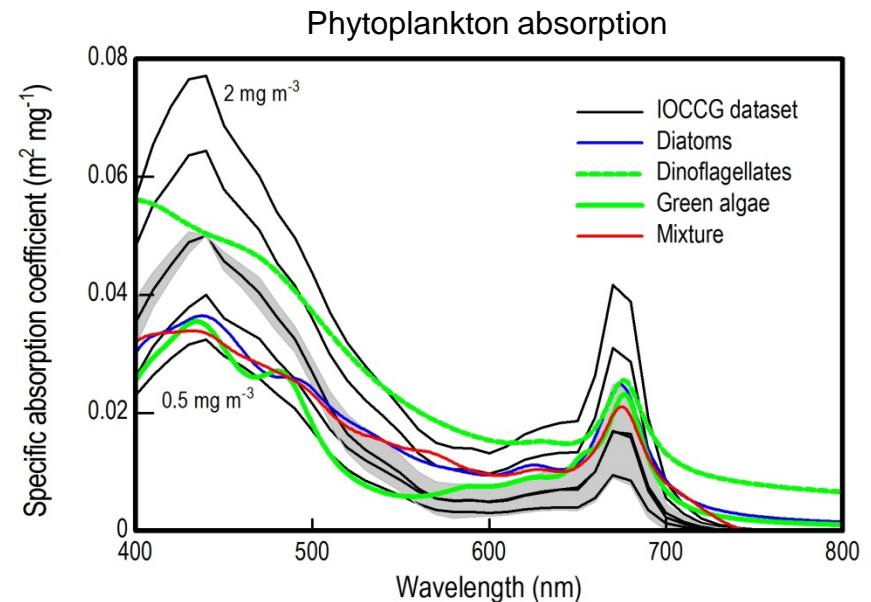
Optical properties

- Phytoplankton: mixtures of 1 – 6 types
 - Specific absorption $a_i^*(\lambda)$ imported from ASCII files
- Suspended matter: mixtures of 1 – 2 types
 - Type 1: Scattering with arbitrary λ –dependency; $b_x(\lambda)$ imported from ASCII file
 - Type 2: Scattering proportional to $(\lambda/\lambda_s)^n$ (Mie scattering)
- Coloured dissolved organic matter (CDOM, Gelbstoff)
 - Specific absorption $a_y^*(\lambda) = \exp[-S(\lambda-\lambda_0)]$; or
 - Specific absorption $a_y^*(\lambda)$ imported from ASCII file
- Detritus
 - Specific absorption $a_D^*(\lambda)$ imported from ASCII file



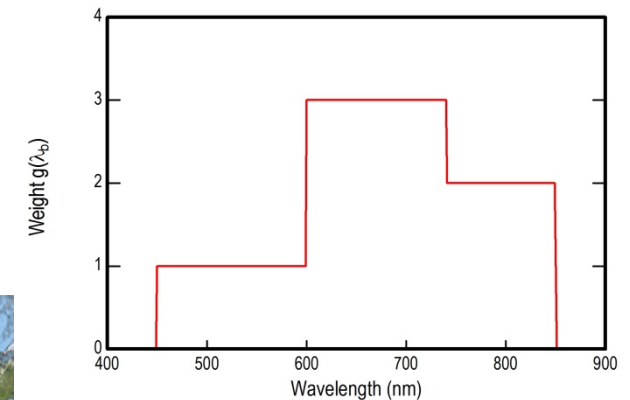
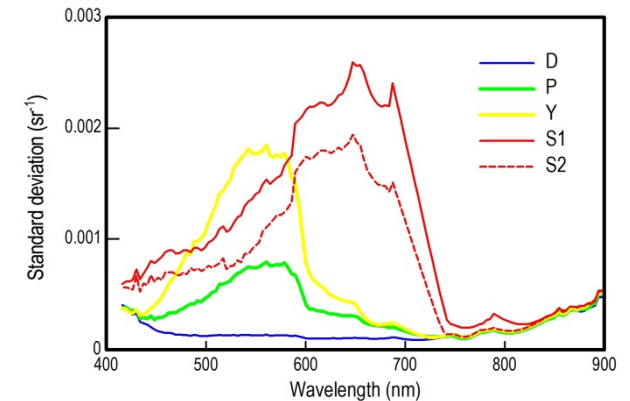
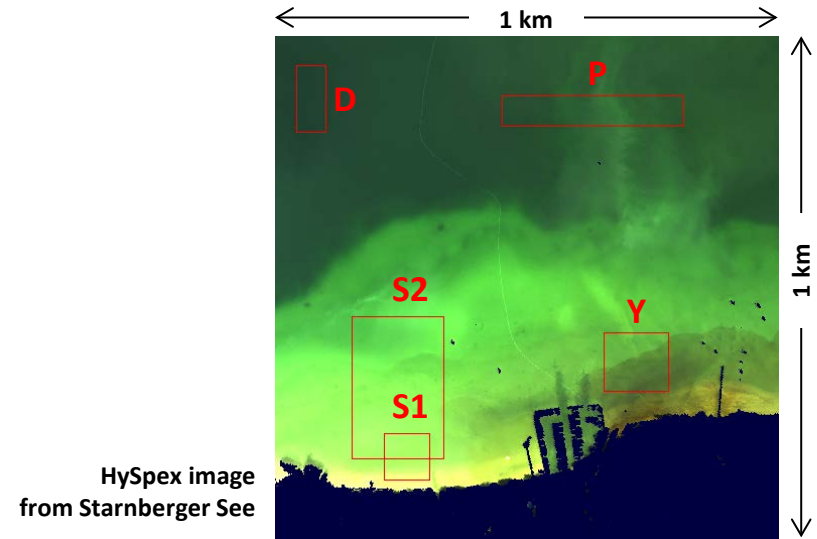
Adaptation

- Model applicable in all aquatic environments (open oceans, coastal waters, lakes ...)
- Data base of inherent optical properties (IOPs)
 - Defaults from Lake Constance (Bodensee) lie well within range of other water types
 - Use site-specific IOPs whenever possible
 - Rank 1: Absorption of CDOM and phytoplankton
 - Rank 2: Scattering
- Sensor properties
 - Center wavelengths
 - Bandwidths (FWHM)



Preparation of data analysis

- Preprocessing
 - Calibration
 - Atmosphere correction
 - Georeferencing
- Adaptation of optical properties
 - SIOPs of water constituents
 - Bottom reflectance
- Preparation of inversion
 - Specify and initialize fit parameters
 - Adjust spectral range and weighting
 - Set thresholds for residuum and no. of iterations



Data processing

Preview of selected fit parameter

Progress bar

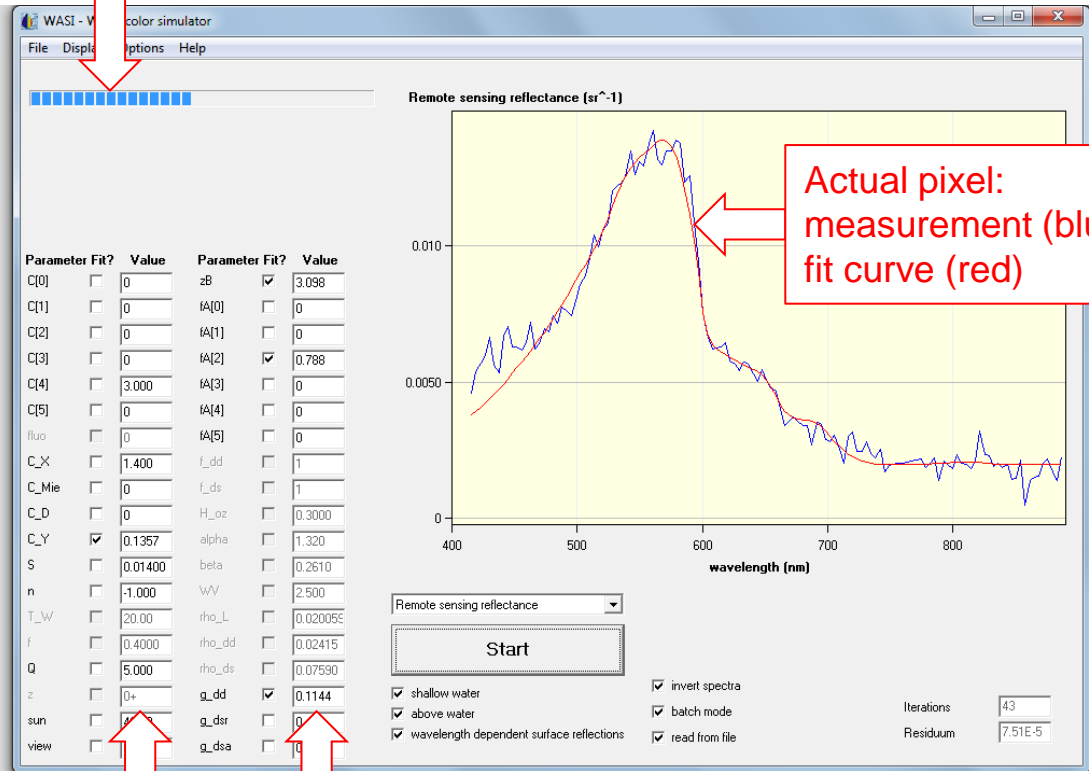
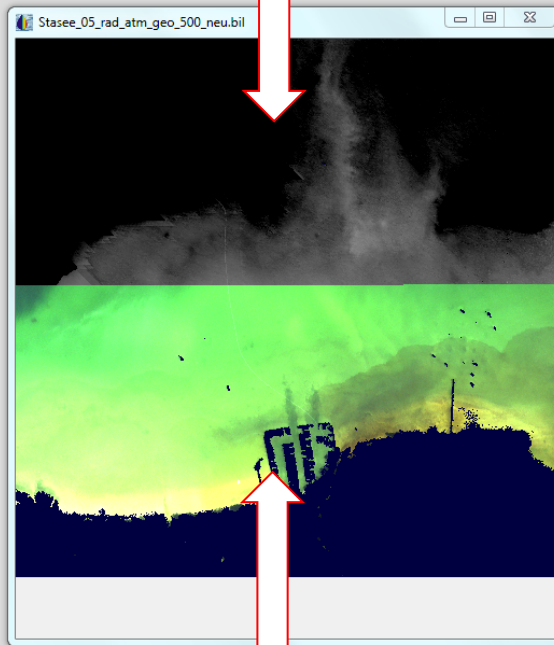


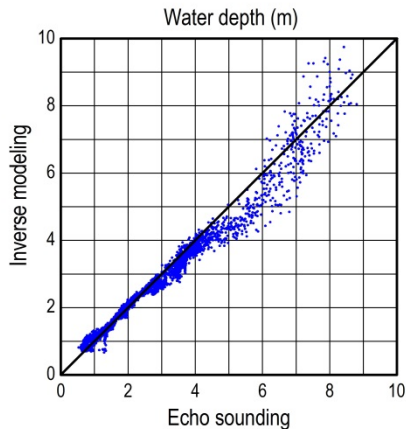
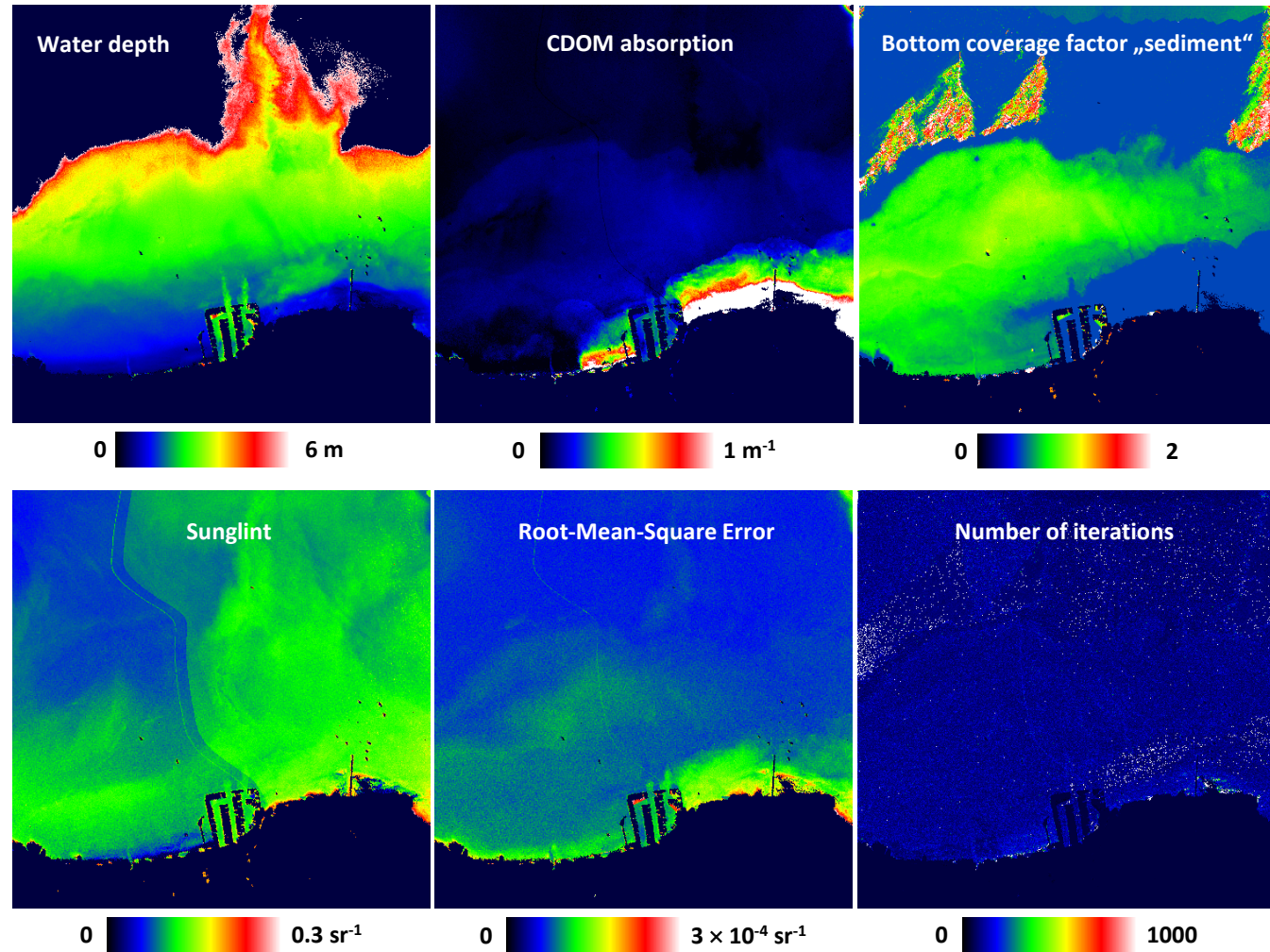
Image preview of 3 selected bands

Actual pixel: (fit) parameters



Validation

- Check plausibility of parameter images
- Validate fit parameters



Summary and Conclusions

- Inverse modelling of atmospherically corrected image data
 - Airborne sensors, satellite instruments
 - Multi- and hyperspectral data
 - Deep and shallow waters
- Regionally optimized data analysis
 - Regional / seasonal adaptation of optical properties
 - Not designed for automated processing of large datasets
 - Requires experienced users
- Intendend for research and education, not for commercial applications

Executable software is on IOCCG page: www.ioccg.org/data/software.html

Sourcecode (Borland Delphi) is available on request: peter.gege@dlr.de

